

WXS
1033

From *Richard B. Francis* to *F. W. Cragin*
yellowst
F
722.9
.A1
no. 176

[FROM THE AMERICAN JOURNAL OF SCIENCE AND ARTS, VOL. XXXI, MARCH, 1861.]

SKETCH OF THE GEOLOGY OF THE COUNTRY ABOUT THE HEAD-WATERS OF THE MISSOURI AND YELLOW STONE RIVERS.

By DR. F. V. HAYDEN,
GEOLOGIST TO CAPT. RAYNOLDS'S EXPEDITION.

WITH AN INTRODUCTORY LETTER BY CAPT. W. F. RAYNOLDS,
U. S. Topographical Engineer.

A. CAPT. RAYNOLDS'S LETTER.

[THE following rapid sketch of the main geological features of the country passed over by the recent expedition to the Head-waters of the Yellow Stone and Missouri rivers, prepared by Dr. F. V. Hayden the Geologist of the Expedition, is submitted for publication by authority of the Honorable Secretary of War.

The district that was examined by the expedition is bounded by the Missouri river on the north and east, by the Platte on the south and by the dividing crest of the Rocky Mountains on the west, and operations were strictly confined to those limits, excepting between the head of Wind river and the Madison fork of the Missouri where the nature of the country was such as to force my division of the party across the main chain of the mountains.

The expedition was in the field for two entire seasons (1859 and 1860) and during about half of the first and the whole of the last season, was divided into two sections or divisions, the first under my immediate control, the second under Lt. Maynadier, U. S. A., the routes travelled over being widely separated so that the amount of labor performed was equal to what would have required three and a half years for a single party; and as operations were all conducted in concert the results must in some respects be more valuable than if obtained by a single party in a longer time.

The total land travel of the different branches of the expedition amounted to nearly five thousand miles independent of having descended in skin and flat boats, the Missouri from Fort Benton to Omaha, N. T., and the Yellow Stone from near the mountains to its mouth.

With the exception of the rivers most of the country had never before been traversed by an exploring party, nor indeed by any whites excepting trappers and not by them for the past fifteen or twenty years.

During the winter months, while the party was stationary on the Platte, Dr. Hayden made a geological examination of the country to the southward along the base of the mountain chain to near Pike's Peak. Dur-

ing the active operations of the party he accompanied that part of the command that was with myself—the geological examinations made by the second division were under the immediate direction of Dr. C. M. Hines of this city.

It is believed that the final results of the expedition will add largely to all branches of the scientific knowledge of the country.

W. F. RAYNOLDS, Capt. Top. Engrs. Comdg.]
Washington, D. C., Jan. 17th, 1861.

B. DR. HAYDEN'S SKETCH.

The observations made during the recent expedition to the head waters of the Missouri and Yellow Stone rivers, under the command of Capt. Wm. F. Reynolds, T. E., have served to extend quite largely our knowledge of the geographical area of the different geological formations already indicated as existing in the far West. I propose in the following paper to present a brief abstract of the leading facts ascertained with a view to their bearing upon the physical geology of the mountain chains. I know that it will be impossible within the limits of a single paper to make every point as clear as could be desired or to use terms in all cases in their usually restricted sense. Much of the country passed over, west of the Black Hills, had never before been explored by scientific men, no maps existed which exhibited its topography with any pretensions to accuracy, and the mountain ranges which were known to exist in that region from information given by traders and trappers were not always laid down in their true geographical localities or with their proper trend, and not until the forthcoming report of Capt. Reynolds, now in course of preparation, appears, can these deficiencies be supplied. Moreover, the wild and broken character of the surface of the country examined, uninhabited except by roving tribes of hostile Indians, precluded the possibility of perfect accuracy in all the minor details, and we can only hope that we have obtained a general idea of the principal geological features of the vast area explored. The rocks observed belong to the different geological periods in the following order:

- I. Granite, Stratified Azoic, and Eruptive Rocks,*
- II. Potsdam Sandstone, (Silurian,)
- III. Carboniferous Rocks, (including Permian, ?)
- IV. Red Arenaceous Deposits,
- V. Jurassic Beds,
- VI. Cretaceous with its divisions,
- VII. Tertiary Deposits.

* By granite or granitoid, I mean those unstratified crystalline rocks in the West which hold a lower position than any of the stratified deposits and for the most part possess a uniform character, forming the central portions of the larger mountains; by stratified azoic, a series of non-fossiliferous stratified beds, apparently sedimentary between the granite and Potsdam sandstone, and by eruptive rocks, those which have been melted by volcanic heat and brought to the surface in a more or less fluid condition, at various periods.

I. GRANITE, STRATIFIED AZOIC, AND ERUPTIVE ROCKS.

Under the first division of my subject I will take up the mountain elevations as they appeared in their detached portions along our route. It is now well known that the term "Rocky Mountains" is quite general in its application including a vast number of more or less important ranges of mountains, which when examined in detail seem to have been elevated with very little regularity and in many instances to be but slightly connected, but when viewed in the aggregate to present a trend nearly northwest and southeast. Before reaching the main range we find along the eastern slope many detached minor elevations showing the wide geographical area under which the elevating forces acted.

I allude in the first place to the Black Hills, the northern portion of which we examined on our route from Fort Pierre on the Missouri to the Yellow Stone river. These Hills form the most eastern outlier of the Rocky Mountains and would seem to be an independent elevation were it not for a low anticlinal which extends across the plain country southward connecting it with the Laramie Mountains. The central portion is composed of a coarse flesh colored feldspathic granite with a series of metamorphic slates and schists superimposed, and thence upon each side of the axis of elevation, the various fossiliferous formations of this region follow in their order, to the summits of the Cretaceous, the whole being more or less inclined against the granitic rocks. The distance across the granitoid nucleus, is from fifteen to thirty miles and on each side of the crest or axis of elevation we find the corresponding portions of the fossiliferous beds from the Silurian to the summit of the Cretaceous. The evidence therefore, is conclusive that all the unchanged sedimentary strata at a period of comparatively recent date extended continuously over the whole area occupied by the Black Hills. The eruptive rocks reveal themselves at various localities as at Bear Peak, Inyan-kara Peak, &c. Bear Peak is a protrusion of very compact igneous rocks, almost isolated from the main range of the Black Hills, and Inyan-kara Peak is for the part composed of pentagonal basaltic columns arranged in a vertical position. There is no evidence however that they were formed by any force independent of that which elevated the entire range of mountains.

The next range that we examined was the Big Horn which is perhaps the most important detached outlier on the eastern side of the main crest of the continent. This seems to trend nearly northwest and southeast, extending into the valley of the Yellow Stone. The nucleus of these mountains is also composed of red feldspathic granite, with a series of stratified azoic rocks; and the unchanged sedimentary strata to the summit of the Cretaceous and including a portion of the Lignite Tertiary can be

seen in regular sequence outward inclining at greater or less angles. From the observations of Dr. C. M. Hines, who acted as Geologist to the exploring division under Lieut. Maynadier, we know that the corresponding formations occur on the opposite side of the axis of elevation and as we remarked of the Black Hills, we may infer from this fact, that the unchanged sedimentary beds once extended continuously over the whole area occupied by the Big Horn mountains, in a nearly horizontal position sometime during the Tertiary period. As we pass along the northeastern base of the Big Horn mountains southwestward, the ridges of upheaval seem to be presented *en echelon*, the range gradually making a flexure around to the westward. Toward the head waters of Wind River this range as it attaches itself to the main chain of the mountains, changes its lithological characters, no true ancient igneous rocks being seen, but instead, lofty peaks composed of eruptive rocks, presenting every variety of structure from compact basalt to porous lava-like masses.

The Laramie mountains, by which we mean the whole range from the Red Buttes to the Arkansaw, were examined with some care from Red Buttes southward nearly to Pike's Peak. There is a remarkable similarity in the general geological features of all the mountains on the eastern slope. The more lofty elevations as Long's and Pike's Peaks with other ridges and peaks scarcely less lofty than those just mentioned, are composed of the same coarse feldspathic granite before alluded to, but the lower ridges are formed to a great extent of a ferruginous feldspathic granite which easily yields to atmospheric agencies, and the surface of the country is paved with crystals of feldspar in consequence of its decomposition. All along the base and often extending up to the crest of the mountains, we see the outcropping edges of the fossiliferous rocks inclining at greater or less angles, and on crossing over into the Laramie Plains we find the corresponding strata leaning from the opposite side. The granitoid nucleus varies from eight to twenty miles in width. No indications of true eruptive rocks were observed in this range. The Medicine Bow and Sweet Water mountains appear to be of the same character for the most part, but on the east side of the Sweet Water river the evidence of igneous action is shown on a large scale. The ancient volcanic material would seem to have been elevated to a great height in but a partially fluid condition and then to have gradually cooled, affecting to a greater or less extent the fossiliferous strata in contact.

Near the junction of the Popo Agie with Wind River, we came in full view of the Wind River mountains which form the dividing crest of the continent, the streams on the one side flowing into the Atlantic, and those on the other into the Pacific. This range is also composed to a large extent of red and gray feldspathic granite with the fossiliferous rocks inclining high

upon its sides. After passing the sources of Wind River, the mountains appear to be composed entirely of eruptive rocks. Even the three Tetons which raise their summits eleven thousand feet above the ocean level are formed of very compact basaltic rock. The Wasatch and Green River ranges, where we observed them have the same igneous origin and the mountains all along the sources of the different branches of the Columbia exhibit these rocks in their full force. In Pierre's Hole, Jackson's Hole and other valleys surrounded by upheaved ridges, these ancient volcanic rocks seems to have been poured out over the country and to have cooled in layers, giving to vast thicknesses of the rocks the appearance of stratified beds.

The mountains about the sources of the Missouri and Yellowstone rivers are of eruptive origin and in the valley of the Madison fork of the Missouri are vertical walls of these ancient volcanic rocks one thousand to fifteen hundred feet in height, exhibiting the appearance of regularly stratified deposits dipping at a considerable angle. As we pass down the Madison we find some beds of feldspathic rocks and mica and clay slates beneath the eruptive layers, dipping at the same angle. After passing the divide below the three forks of the Missouri we see a number of partially detached ranges which appear to be of the same igneous character. In the Belt, Highwood mountains and indeed all along the eastern slope in this region we find continual evidence of the outpouring of the fluid material in the form of surface beds or in layers thrust between the fossiliferous strata. These igneous beds thin out rapidly as we recede from the point of effusion. A large number of these centres of protrusion may be seen along the slope of the mountains west of the Judith range. The erupted material sometimes presents a vertical wall three hundred feet high, then suddenly thins out and disappears. The Judith, Bear's Paw and Little Rocky Mountains seem to be composed for the most part of granite and other rocks, with igneous protrusions here and there. I have in a former paper expressed the opinion that the central portions of our mountain ranges are composed of feldspathic granite and to a certain extent this is true in regard to the more eastern outliers, but more recent observations have convinced me that these rocks which I have defined by the term eruptive compose by far the greater portion of the mountain masses of the west.

II. POTSDAM SANDSTONE. (*Silurian*.)

The discovery of this formation in its western extension has already been announced in a former paper.* It was first made known as occurring in the Black Hills and resting upon the upturned or nearly vertical edges of the schists, clay slates and granitoid rocks, and the inference was drawn that the same rocks

* This Jour., [2], xxvi, 276.

would be found forming an outcropping belt all along the eastern slope of the Rocky Mountains. After leaving the Black Hills we next observed it along the margins of the Big Horn range near the summit, holding the same relative position and exhibiting the same lithological characters. A few thin layers of fine calcareous sandstone were observed filled with fossils characteristic of this period. At the head of LaBonte creek in the Laramie range I noticed a bed resting discordantly upon azoic slates, fifty to one hundred feet in thickness, holding the same position and possessing the same lithological characters which it reveals at other localities. I could discover no fossils in it at this point but I am confident that this bed represents the Potsdam sandstone. The same bed seems to occur all along the mountains from Laramie Peak to Cache la Poudre creek underlying the well-known Carboniferous strata and resting upon the decomposing granitoid rocks, which form the nucleus of the first ridge. This rock (the Potsdam) is more or less changed by heat from beneath, but I was able to trace it continuously from the source of the Chugwater creek to the source of Cache la Poudre, a distance of over one hundred miles. It was also seen along the eastern slope of the Wind River mountains but did not contain any organic remains.

The above facts show very clearly that in its western extension, the primordial zone of Barrande is represented only by a thin bed of sandstone never exceeding one hundred and fifty feet in thickness, and that is seen only in a very narrow outcropping belt near the margins of the mountain crests. The stratified azoic rocks upon which it rests discordantly so far as my observations have extended, never reach a very great thickness in the west.

III. CARBONIFEROUS ROCKS, (INCLUDING PERMIAN?).

On both sides of the divide of the Rocky Mountains, so far as our explorations have extended, a series of calcareous, arenocalcareous and arenaceous beds are seen which we have referred to the Carboniferous epoch. They vary in thickness at different points. Without specifying localities it will be sufficient to remark that all along the margins of any of the mountain elevations in the far West, these rocks are seen in a more or less inclined position.

Sometimes they are not visible for a short distance (as between the Laramie and Platte Rivers, twenty or thirty miles), but it is plain that they have either been removed by erosion, or concealed by more recent deposits. Along the Big Horn mountains there are alternate layers of sandstone, arenaceous and magnesian limestones, many of which show oblique laminæ and other indications that their deposition took place in shallow and perhaps turbulent waters. They are here developed to a thickness of one thousand

to fifteen hundred feet and incline high upon the sides of the mountains at an angle of 50° to 70° . They contain few fossils but these indicate rocks of the same age as those in the Black Hills. Along the Laramie mountains, from the Red Buttes to Pike's Peak, apparently the same limestones are seen inclining against the sides of the elevated ridges at greater or less angles and on the opposite side of the axis sloping down to the Laramie plains the corresponding strata are seen, though leaning at much smaller angles, usually from 9° to 15° . Along the Sweet Water and Wind River mountains these rocks are highly developed and incline against the sides of the ridges of elevation as heretofore described. The corresponding portions are also seen on the west slope of the main range at the sources of Green and Snake Rivers but not as conspicuously developed, the eruptive rocks predominating. Crossing back over the dividing crest near the sources of the Madison, Jefferson and Gallatin Forks of the Missouri, we find similar limestones largely developed and covering a considerable area on the eastern slope. Near the junction of the three forks and along Smith's or Kamas River we find them reaching a thickness of eight hundred to one thousand feet, often partially changed by contact with igneous rocks beneath. They were also observed around the Judith Mountains and also about the Bear's Paw and Little Rocky Mountains.

Nowhere in the Rocky Mountain range so far as my observations have extended, do the Carboniferous rocks seem to abound in organic remains and the few usually seen are generally found in a bad state of preservation and comprise a limited number of species. The precise period to which these rocks belong, which are so persistent in all disturbed regions, is not positively known, the evidence from organic remains pointing to the age of the Coal measures and sometimes to that of the Lower Carboniferous Period; probably both members of the system occur there.

At the foot of the Big Horn mountains near the head of Powder River, I observed at one locality a series of beds which indicated the presence of Permian rocks. These beds which are composed of cherty magnesian limestone are very much like those already described in northeastern Kansas and contain in great abundance some of the same species of fossils as *Myalina perattenuata* and others. I have also seen similar limestones in other localities but no fossils were detected and though having a Permian appearance they may belong to the upper portion of the Carboniferous.

The evidence is clear in many localities that prior to the deposition of the Red Marls succeeding the supposed Permian, a very great erosion of the surface of the Carboniferous rocks took place. We find, for example, in many localities only a thin representation of the Carboniferous rocks and again a full development, one thousand to fifteen hundred feet in thickness.

IV. RED ARENACEOUS DEPOSITS.

Overlying the Carboniferous rocks and equally persistent with them is a series of red arenaceous Marl beds or gypsum-bearing marls which are coëxtensive with the upheaved sedimentary formations along the Rocky Mountains. The largest development of these beds which I have observed, occurs on the northeastern side of the Big Horn mountains and on the west slope of the Wind River mountains near the source of the Gros Ventres Fork of Snake River. From the Red Buttes on the North Platte to Pike's Peak these beds are often removed by erosion or concealed by superficial deposits, but their appearance in numerous places shows very clearly that beneath the surface they occupy a considerable area throughout the country bordering the mountain ranges, possibly extending entirely over the eastern slope. Passing over into the Laramie Plains we find that the red marls constitute the surface formation of the plain country. It has also been shown from Mr. H. Engelmann's explorations that these beds are revealed along the Wasatch Mountains, even south of Lake Utah, furnishing undoubted evidence that they belong to the same great deposit. The fact also that one thousand to fifteen hundred feet of red arenaceous beds are seen near the sources of Green River, leads to the inference that they continue southward far down the Green River valley to that portion which takes the name of Colorado, and are in fact a continuation of the extensive red deposits, described by various explorers in New Mexico.

These red beds are also seen under similar circumstances highly developed along the mountains at the sources of the Missouri. There seems to be a change in the lithological characters below the Gate of the mountains, the peculiar red deposits disappearing for the most part and a series of irregular layers of siliceous limestone with a reddish tinge, and with oblique laminae, ripple mark and other indications of shallow water deposition. It is through these layers of rock that the Missouri River cuts its way from the foot of the mountains to the mouth of High Wood creek, about ten miles below the falls. They are also distinctly revealed around the Judith mountains. Along the Big Horn mountains thick layers of gypsum occur, but the gypsum beds are by no means co-extensive with the red deposits, and indeed are present in but few localities. Near the head of Powder River the aggregate thickness of the gypsum strata is about one hundred feet while near the source of Snake River there is a thickness from fifty to eighty feet. It also occurs to a considerable extent at the foot of the mountains, on La Bonte creek, a branch of the North Platte.

V. JURASSIC ROCKS.

These rocks are everywhere revealed, overlying the red deposits just mentioned and possessing an equal geographical extension. Their fullest development and most fossiliferous condition seems to be along the margins of the Black Hills where they have furnished the most satisfactory evidence of their age. Along the northeastern slope of the Big Horn mountains, this group of rocks presents its usual appearance of grey and whitish calcareous and arenaceous layers, with indurated somewhat variegated beds of more or less laminated marls, containing in great abundance *Belemnites densus*, *Pentacrinus asteriscus*, a new species of *Ostrea*, *Pecten*, &c.

At Red Buttes we find a fair development of these beds with the same fossils, but as we proceed southward toward Long's Peak, the intercalated laminated marls disappear and the whole formation seems to be reduced to a thickness of fifty to one hundred feet, with very few fossils. Along the southwest side of the Big Horn mountains and the northeast side of the Wind River mountains we have a thickness of Jurassic rocks from eight hundred to one thousand feet containing organic remains in the greatest abundance. Crossing the Wind River mountains we observed the strata corresponding to those upon the eastern side with *B. densus*, *Ostrea*, &c. Returning to the eastern slope at the sources of the Missouri we see occasional indications of their existence, but not so conspicuous as to be readily identified. The age of this group of rocks may be now considered as thoroughly established, so great a number of fossils which appear to be of undoubted Jurassic forms have been obtained.

I have remarked that the older fossiliferous beds doubtless pass beneath the more recent Cretaceous and Tertiary deposits and occupy a greater or less area underneath the prairie country east of the 'divide' of the Rocky Mountains. I have made this inference from the fact that where any elevations occur the complete series of fossiliferous beds are exposed around the axis of upheaval. That I may be not misunderstood by those geologists who have colored large areas Triassic and Jurassic on geological maps of the West, I would say, that I have never seen any of the older fossiliferous rocks from the Potsdam to the Jurassic inclusive, exposed except in narrow outcropping belts around the margins of the mountain elevations. The Carboniferous rocks occupy a belt from one to two miles wide, and the red arenaceous deposits are exposed over about the same area, while the Jurassic form a zone never more than one-fourth of a mile to three miles in width.

VI. CRETACEOUS ROCKS WITH SUBDIVISIONS.*

The various subdivisions of the Cretaceous group in the West were observed at numerous localities. The strata in many places occupy large geographical areas, holding a horizontal position, in others forming a belt or zone of greater or less width around the mountain elevations. No. 1 is a well marked and distinct division along the Missouri River from Desoto to a point above the mouth of the Big Sioux River in the eastern portions of Kansas and Nebraska and in the south and southwest. But when we come into the vicinity of the mountain ranges in the northwest its typical form is wanting, and apparently an increased development of No. 2 only is seen. Along the Big Horn mountains, No. 2 is eight hundred to one thousand feet in thickness, composed of black, plastic clay with several layers of gray and yellowish calcareous sandstones ten to fifty feet in thickness. Along the Laramie and Wind River mountains the same characters are shown. After leaving the Missouri near the mouth of the Niobrara river No. 3 is never seen presenting its typically marly character. In the vicinity of the Black Hills we saw a series of beds composed of alternate thin layers of arenaceous and argillaceous sediments with *Ostrea congesta* and *Inoceramus problematicus* which may possibly represent No. 3. Along the Big Horn mountains and from Red Buttes to Cache la Poudre creek the same fossils were often found and some other indications of its existence, but no well marked typical beds were seen. It is now well-known that *O. congesta* and *I. problematicus*, range down into No. 2, so that No. 3 in the west and southwest may give place to an increased development of No. 2. Nos. 4 and 5 are largely developed every where, when not concealed by the overlying Tertiary deposits, especially along the Laramie mountains and in the valley of Cache la Poudre. In the Valley of Wind River all the Cretaceous rocks down to No. 2, appear to have been removed by erosion prior to the deposition of the Tertiary Beds, and the characteristic fossils of No. 2, are quite abundant. As we pass over mountains, we have inclining from the western slope, six to eight hundred feet of alternations of black plastic clays, arenaceous marls and beds of sandstones and limestone with a few seams of Carbonaceous matter passing up into calcareous and arenaceous compact rocks. In some arenaceous limestones near the middle of the series and extending upward, quite abundant fossils were observed, among them a large *Inoceramus*, two species of *Ostrea*, a large *Pinna*, four inches in length, a *Cardium* and a number of undetermined species with fragments of silicified wood. The general dip of these rocks is about 20°. These

* The Cretaceous rocks of the West have been divided into five formations, numbered 1, 2, 3, 4, &c. A more careful study of No. 1? may render it necessary to make other divisions.

well marked Cretaceous beds pass up quite imperceptibly into an enormous thickness of Lignite Tertiary. Passing over the dividing crest to the head waters of the Missouri, we did not observe any indications of Cretaceous rocks until we had descended below the three forks, where we find traces left after erosion. They do not reveal themselves conspicuously until we arrive within twenty or thirty miles of Fort Benton where the black plastic clay begins to overlap the Jurassic rocks with its characteristic fossils, and on reaching Fort Benton the plastic clay is quite homogeneous and is developed to a thickness of eight hundred feet. As we proceed toward the mouth of the Judith River and near the Judith mountains we find quite thick beds of concretionary sandstone which form the "Stone Walls," "Citadel," &c. It is from these beds that we have obtained a group of fossils which we have referred provisionally to No. 1, but which seem to be specifically distinct from all others in the West. It may be that when this group of beds now referred to Nos. 1 and 2, comprising a thickness of fifteen hundred to two thousand feet in this region are more carefully studied that several subdivisions will be made, having equal importance with the others. During the past season our route led us along the 'divide' between the Missouri and Yellow Stone rivers south of the Judith mountains, so that we passed outside of any good exposures of No. 1, as well as beyond the limits of the estuary beds at the mouth of the Judith. We must await a more thorough and detailed exploration of this region before we can state with entire confidence the succession of the beds.

VII. TERTIARY DEPOSITS.

In speaking of the Tertiary deposits of the Northwest, so far as known at the present time I propose to separate them into four divisions which will be sufficient for our immediate purposes. 1st, Estuary Deposits. 2nd, True Lignite Beds. 3rd, Wind River Valley Deposits. 4th, White River Tertiary Deposits.

The estuary deposits, of which the Judith basin may be regarded as the type, are quite remarkable and of a most interesting character. Opinions of a somewhat conflicting nature have been entertained in regard to them, owing to the peculiar character of the organic remains, but recent observations have convinced me that they are all of Tertiary age and that they are quite widely distributed throughout the far West. The lithological characters of the Judith deposit have already been sufficiently described and it has yielded many important fossils. A thin series of beds is also found near the sources of the Moreau, Grand and Cannon Ball rivers, and at the mouth of the Big Horn river we have a group of beds eight hundred to one thousand feet in thickness with fossils of the same character as those

occurring at the mouth of the Judith. The researches of Mr. H. Engelmann, in Utah, have also established the existence of an estuary deposit in the country bordering upon Green river,—scarcely less interesting than that of the Judith. These deposits pass up into the true lignite beds without any perceptible line of separation gradually losing their estuary character and ever after containing only land and freshwater shells. The lignite strata are chiefly remarkable for yielding in the greatest abundance, finely preserved vegetable remains. A few fragments of leaves of Dicotyledonous trees and silicified wood, with very impure lignite beds, are formed in some of the estuary deposits but no groups to indicate the great luxuriance of vegetation which must have existed during the accumulation of the lignite strata.

The geographical extension of the lignite deposits of the West is now a matter of the highest interest, and from what is already known, I am convinced that they will yet be found to cover a greater or less area on both sides of the main 'divide' of the Rocky Mountains, from the Arctic Sea to the Isthmus of Darien. The estuary and lignite beds seem also to have partaken equally with the older fossiliferous rocks, of the influence which elevated the mountain chains. Along the Laramie mountains, and from the Red Buttes to the 'divide' between Platte and Wind rivers along the Big Horn mountains the strata incline at very high angles 40° to 80° and in some instances are very nearly vertical. The true lignite strata seem to conform to the older fossiliferous rocks and to have been disturbed by the same influences that elevated the mountain ranges in the vicinity. These Tertiary beds extend over all the plain country to the north, and east of the Laramie mountains, far to the northward, beyond the limits of our explorations. Crossing the Wind River mountains, we find them largely developed high upon the western slope, dipping at a high angle, from the Wind River range on the one side, and the Wasatch and Green River mountains on the other.

Throughout the Wind River valley is a series of beds of great thickness which seem to be intermediate in their character between the true lignite beds and the White River Tertiary deposits. We first observed them gently inclined near Willow Springs on the North Platte and thence westward toward the Sweet Water mountains, and near the 'divide' between the North Platte and Wind River they reach a thickness of four hundred feet. From this 'divide' throughout the Wind River valley they occupy the greater portion of the country and though inclining in the same direction with the older strata the beds do not dip more than 1° to 5° . They differ from the other deposits in the great predominance of arenaceous sediments and in the absence of vegetable remains, but they contain fragments of turtles and

numerous fresh water and land shells of the genera *Helix*, *Planorbis*, *Vivipara*, etc. The entire thickness of these deposits may be estimated at from fifteen hundred to two thousand feet. From the fact that these deposits do not conform to the true lignite beds and that detached portions are seen lying upon the sides of the mountains but slightly inclined, while the corresponding beds are shown in the valley below, we infer that they were accumulated long before the mountains were raised to their present height or perhaps during the gradual process of elevation. This is especially shown at the upper end of the Wind River valley. Passing over the Wind River mountains we again see them holding the same position on the western slope and possessing the same lithological characters. While the lignite beds on the west side of the 'divide' incline at a large angle, the more recent beds although in some places occupying the very crest of the mountains, seldom incline more than 3 to 5 degrees.

The most interesting additional facts which we have obtained in regard to the White River Tertiary beds, are their geographical extension and the evidence of their age in relation to the lignite deposits. We can now show beyond a doubt that the former must have been accumulated long since the latter. We have ascertained that they extend southward along the Laramie Mountains to Willow Springs within ten miles of Cache la Poudre, that they also extend up the North Platte to the Box Elder creek, and even beyond are small outliers, showing that much has been removed by erosion. Passing over into the Laramie Plains we find at the source of the Box Elder and extending over to the head of Bates Fork a large development of this Tertiary and it also reaches far westward to the Medicine Bow mountains. We also know from the observations of Dr. Hines that it occupies a considerable area among the Sweet Water mountains extending over into the Green River valley. We have along the North Platte the overlapping of the White River beds upon the lignite strata, thus affording the evidence of superposition for their relative age. The same fact was noticed between the north fork of the Shyenne and the head of Cherry creek where beds of marl and limestone containing *Planorbis*, *Limnea*, etc., the same as are seen in the Bad Lands proper, repose upon true lignite Tertiary strata. Again, while the White River beds hold for the most part a horizontal position, those of the lignite Tertiary are often much disturbed. Near the Black Hills the former seem to have been elevated to a considerable height by the upheaval of the mountains, but they do not in any case incline more than 1° while north of the Black Hills the lignite beds dip 5° to 10°. Along the Platte I have seen the former inclining 5°, especially on La Bonte creek and about

fifteen miles east of the mouth of that creek. Often the beds seem to have been raised up several hundred feet above their original position, without inclination, resting upon the upturned edges of the lignite beds which we have before observed, partook equally of the disturbing influences which have given so great an inclination to the older fossiliferous rocks. Along the Big Horn mountains and the North Platte the lignite beds sometimes incline from the foot of the mountains 80° and often the influence of the elevatory power has affected them far out into the plain country.

In the above accounts of the Tertiary deposits of the West we have shown that the older members are clearly separated into four divisions exclusive of the Pliocene deposits of the Niobrara. Let us examine the evidence in regard to the age of these deposits. If we study the upper portions of Cretaceous formation No. 5 when not removed by the erosive power of water to any great extent, we then observe from the time we pass from No. 4 to No. 5 a gradual change in the sediments and other indications of a slow approach to shallow water, arenaceous sediments begin to take the place of argillaceous so that we have alternate thin layers of sand and clay, the sand continuing to increase until the upper part becomes a yellow ferruginous, coarse sandstone with most conspicuous examples of ripple-mark and oblique laminæ. As the waters of the Cretaceous sea were gradually receding, toward the Atlantic on the one side, and toward the Pacific on the other, remnants were left in the form of lakes, estuaries, etc., which now afford us the last indications of marine and brackish water deposits in the central portions of the West. In these deposits we have first a mingling of brackish and fresh-water forms, gradually passing up to pure fresh-water and terrestrial species, with no return to the marine condition again.

In the upper part of the Cretaceous formation No. 5, on the Moreau, we find the *Ostrea subtrigonalis*, and in the Judith deposits a form occurs in the greatest abundance which is undistinguishable from it.

We have also mentioned the fact that the fossils of upper part No. 5 seem to have existed upon the verge of the Tertiary period, that they sometimes present peculiar forms more closely allied to Tertiary types than Cretaceous and were it not for the presence of the genera *Baculites*, *Ammonites*, *Inoceramus*, etc., which are every where supposed to have become extinct at the close of the Cretaceous epoch, we would be in doubt whether to pronounce them Tertiary or Cretaceous. These facts would seem to indicate a foreshadowing of the Tertiary era and that the transition from one great period to the other was gradual and quiet, the change in the physical conditions being ultimately sufficient to

destroy the Cretaceous fauna and bring into existence that of the Tertiary. Again, in numerous localities where No. 5 is fully developed and a large thickness of Tertiary deposits is superimposed, so that near some of the mountain elevations I have found it difficult to draw the line of separation, no apparent physical break occurring in the sediments.

Will not these statements go far to show that the estuary deposits ushered in the dawn of the Tertiary epoch and induce the belief that they belong to the first part or Eocene period? This point is an important one to establish, on account of its bearing upon the history of the physical development of our western continent.

The estuary deposits soon lose their marine and brackish character and gradually pass up into the true Lignite strata, of purely freshwater origin, thence by a slight discordancy into the Wind River valley beds, which give evidence of being an intermediate deposit between the true lignite and White river Tertiary beds. Then come the White river bone beds which pass up into the Pliocene of the Niobrara by a slight physical break, and the latter are lost in the Yellow Marl or Lacs deposits. I have estimated the entire thickness of Tertiary rocks in the Northwest at from five to six thousand feet, and their interest will be appreciated when I venture to suggest that by thorough investigation they will doubtless reveal in a most remarkably clear manner the history of the physical growth and development, step by step, of the central portion of this continent. I shall treat this subject more fully in a future paper, and would refer to the forthcoming Report of Capt. Reynolds for the details of the facts sustaining my opinions.

We have no evidence, so far as I know, of long continued deep-water deposits in the west, until far up in the Cretaceous period. If we examine the Potsdam sandstone we shall find that where it reaches its greatest force, the lower portion is composed of an aggregation of quartz pebbles cemented with siliceous matter, and as we pass upward we find it arranged in thin layers quite compact with fucoidal markings, ripple-mark, &c. Everywhere are most abundant examples of oblique laminæ of deposit, and ripple and wave-markings—evidences of shallow waters.

During the long period that elapsed between the deposition of the earliest part of the Silurian epoch and the commencement of the Carboniferous, we have reason to believe that dry land prevailed over a large portion of the west. The Carboniferous epoch commences with thin layers of arenaceous deposits gradually passing up into homogeneous siliceous and calcareous beds. The latter are never more than from twenty to fifty feet in thickness, and then the arenaceous sediments begin again to predominate and all the proofs of shallow as well as turbulent waters are shown. We then pass up through the red arenaceous de-

posits and Jurassic beds, and find no rocks that indicate deep water deposition. Cretaceous formation No. 1 commences in many places with a considerable thickness of an aggregation of water-worn pebbles passing up into thin alternate layers of arenaceous and argillaceous sediments with thick beds of sandstone with ripple markings and oblique laminæ, then gradually ceases in No. 2 and through Nos. 2, 3 and 4, the sediments indicate that they were accumulated in comparatively deep and quiet waters. No. 2 is a black plastic clay, No. 3 grey marl, and No. 4 a dark indurated sometimes laminated clay with many calcareous concretions. In No. 5 we gradually approach indications of shallow water until dry land appears, as already stated.

It will not be possible at this time to mention in detail all the oscillations of surface and other physical changes to which we have reason for supposing the country was subjected during all these periods. It is sufficient for our present purpose to show that except during the middle Cretaceous epoch no long continued periods of quiet water prevailed in these ancient western seas.

The evidence appears to me to point to the conclusion that a much milder climate prevailed throughout the western portions of our continent, during a greater part of the Tertiary period than that which exists in the same latitudes at the present time. The organic remains appear to indicate a subtropical climate or one similar to that of our Gulf States. Near the close of the Cretaceous epoch the waters of the great Cretaceous sea receded toward the present position of the Atlantic on the one side and toward that of the Pacific on the other, leaving large areas in the central portions of the west, dry land. These areas were of course proximity to the sea and comparatively but slightly elevated above the ocean waters. In regard to the Mollusca which have been found quite abundantly entombed in the lignite-bearing strata, it is an interesting fact that the most nearly allied living representatives of many of these species are now found inhabiting the streams of Southern Africa, Asia, China and Siam, apparently indicating the existence of a tropical climate in these latitudes at as late a period as the Tertiary epoch.*

Again, the luxuriance of the flora which has been so perfectly preserved in the lignite strata of the West point to the same conclusion. It is true that until recently no species have been found which belong exclusively to a tropical vegetation, but during our last expedition we obtained a species of true fan palm, very closely allied to *Sabal lamonis*, figured by Dr. Heer in his "Flora Tertiaria Helvetiæ." "The most northern limit of palms is that of *Chamærops palmetto*, in North America in lat. 34°-36°, and of *Chamærops humilis* in Europe, near Nice, in 43°-44° N.

* See Memoir by F. B. Meek and F. V. Hayden, in Proc. Pa. Acad., June, 1856.

lat.”* The true palms of our present day are considered as having their native land within the tropics. That this or a similar condition of climate continued throughout the accumulation of the Wind River valley deposits may be inferred from their Molluscan remains which are more nearly allied to tropical forms.

Again, we have in this region, as before mentioned, a vast area occupied by the lignite-bearing strata. There are from thirty to fifty beds of lignite varying in thickness from one inch to seven feet. Over all this vast area there are at the present time no large forests, no timber except that which skirts the streams. We now know that during the Tertiary period vast forests of timber must have covered many portions of the far West from the abundance and variety of the vegetable remains preserved in the rocks. Silicified trunks of trees, fifty to one hundred feet in length and two to four feet in diameter, and stumps which indicate gigantic forest trees occur abundantly over hundreds of square miles along the Missouri and Yellow Stone rivers. Prof. Henry and other meteorologists have arrived at the conclusion from a vast number of well authenticated facts that the absence of forest trees on the great prairies of the far west is due to the want of moisture which is well known to prevail all along the eastern slope of the Rocky Mountains. The prevailing winds are now known to come from the west, and as the currents of air laden with moisture from the Pacific ascend the western slope of the mountains, become condensed and deposit their burdens for the most part before reaching the eastern slope.

Prof. Henry, in his paper on Climatology contributed to the Patent Office Report for 1856, says: “the return westerly current, sweeping over the Pacific Ocean, and consequently charged with moisture, will impinge on the Coast range of mountains of Oregon and California, and, in ascending its slopes, deposit moisture on the western declivity, giving fertility and a healthful climate to a narrow strip of country bordering on the ocean, and sterility to the eastern slope. All the moisture however will not be deposited in the passage over the first range, but a portion will be precipitated on the western side of the next, until it reaches the eastern elevated ridge of the Rocky Mountain system, when, we think, it will be nearly if not quite exhausted.” We are now supposing that the climatic conditions—winds, currents of air, &c., did not differ to any great extent during the Tertiary epoch from those which prevail in the same latitudes at the present day. We therefore venture the suggestion that up to the time of the accumulation of the middle Tertiary deposits the lofty barrier of the Rocky Mountains did not exist.

* Lindley's Vegetable Kingdom, p. 136.

Washington, D. C., January 20, 1861.

AM. JOUR. SCI.—SECOND SERIES, VOL. XXXI, No. 92.—MARCH, 1861.

